A REPORT ON A BIOLOGICAL SURVEY OF THE WATERS RECEIVING WASTES FROM SHERMAN MINE, TEMAGAMI, ONTARIO.

1974

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Ministry
of the
Environment
Ontario

MINISTRY OF THE ENVIRONMENT

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SUMMARY AND CONCLUSIONS

1. The Sherman Mine complex has caused impairment of a local area in the vicinity of the mining and milling site including:

(a) changes in the water chemistry,
(b) a change in the apparent colour of the water,
(c) a depression of the stream bottom fauna community.

Significant impairment as indicated by the response of the bottom fauna was limited to an area immediately adjacent to the mining complex and did not extend downstream of the outlet of Tetapaga Lake. The zone of effect was restricted to the tailings impoundment basin as it presently exists, to the future impoundment basin, and the existing water recirculation system.

2. The impairment of the aquatic community extended farther downstream in 1972 than was indicated during the 1969 post-operational survey. In 1969, significant impairment was restricted to station 8 (outlet of Vermilion Lake tailings area) while during the 1972 survey a depressed bottom fauna community was detected downstream to station 2.

3. Evidence of the potential for an "acid-mine" waste problem exists. At the present time this condition is confined to the mine property only, particularly the South Pit, and no discharges are occurring from areas demonstrating severe acid-mine problems.

RECOMMENDATIONS

1. Sherman Mine should continue to keep an aerial photographic record of the downstream extent of the colour problem generated by their effluent to determine if the perimeter of the colour is migrating downstream.

2. An investigation of waste loadings to the tailings disposal area and the characteristics of the contained tailings should be conducted to determine if the potential for an acid-mine problem exists. As well, the company should determine the quantity of sulphuritic material that will be encountered in the mining programme. An early indication of the potential for an acid-mine drainage problem would allow for the establishment of a preventative system to ensure that the downstream waters do not become acidified.

3. Waste effluent streams, including the open pit waters where a potential acid-mine problem exists, should not be discharged without neutralization.

4. It is important that an analytical method be developed to evaluate the effectiveness of the polyelectrolyte additions.

1. INTRODUCTION

1.1 History, Purpose and Scope

In 1965, Sherman Mine proposed the development of an iron ore mine near the Village of Temagami. At a public hearing in Temagami in November, 1966, the Company presented a brief outlining their proposals for development and plans for waste disposal. The plans were brought into effect and the mine commenced operation in 1968. During March, 1969, the Company's tailings disposal area commenced to overflow to the Tetapaga River system.

In 1967 and 1968 the Biology Branch of the former Ontario Water Resources Commission completed surveys on the natural drainage systems likely to be affected by the mining activity. The purpose of the two surveys was to collect background information to permit an assessment of alterations in water quality which might result from the operation of this mine.

In July, 1969, after five months of overflow from the waste disposal area to the Tetapaga River system, the first post-operational survey was completed. In August, 1972, the second post-operational survey was conducted.

It is the purpose of this report to present the results of the 1972 survey and compare the present status of the aquatic environment with conditions which existed during the pre-operational surveys of 1967 and 1968 and the initial post-operational survey carried out during 1969.

1.2 Description of the Study Area

The Sherman Mine complex occupies portions of the Townships of Chambers, Briggs and Strathy, west of the Village of Temagami, in the District of Nipissing. The mill is located in the southeast portion of Strathy Township and the operation contacts the headwaters of two drainage basins:

(i) to the northeast, through Link Lake and Johnny Creek to Net Lake, thence to the Matabitchuan River. The Matabitchuan River flows to Lake Temiskaming - the headwaters of the Ottawa River.

(ii) to the south through the Tetapaga River and the Northeast Arm of Lake Temagami. Lake Temagami feeds the Sturgeon River flowing to Lake Nipissing and thence to Georgian Bay via the French River.

The major waste receiver for the Sherman Mine complex is the Tetapaga River system. Periodically a limited amount of mill waste is discharged to the Link Lake drainage.

The major flow pattern for the mill wastes is to the Vermilion Lake tailings area, through Wilhelmina and O'Connor Lakes to Tetapaga Lake, the Tetapaga River and the Northeast Arm of Lake Temagami. Under planned expansion the ultimate boundary of the tailings disposal area will include O'Connor, Wilhelmina and Vermilion Lakes. Iron Lake forms a part of the west pit area and is kept de-watered by pumping to Iron Creek upstream of Tetapaga Lake.

During the 1972 survey,sampling locations were selected with reference to earlier surveys to provide a base for comparative interpretation. The locations of the sampling stations are provided in Table 1.2.1 and illustrated in Figure 1.2.1.

1.3 The Mining Operation

The iron ore is removed by open pit operations in a banded-iron (taconite) formation and is trucked to the milling complex. After crushing, the magnetite (iron oxide) is separated magnetically and pelletized for shipment to the Dofasco steel works in Hamilton.

The waste consists of finely ground rock fragments - predominantly chert, having 8 - 10% total iron content and ranging in size from 20 - 500 mesh. The waste is conveyed as a slurry to the tailings disposal area. The retention time and slow flow in the disposal area allows the suspended solids to settle and the clarified water overflows via a decant weir to the Tetapaga River. Some of this overflow is recycled to the mill circuits.

The major liquid waste sources and their receiving waters are summarized in Table 1.3.1.

TABLE 1.2.1

SUMMARY AND DESCRIPTION OF SAMPLING STATIONS

STATION REFERENCE	LOCATION	DATE 1967-68	1969	1972
1	Tetapaga River (at #1 Weir)	C/B	C/B	C/B
2	Creek (at #2 Weir)	C/B	C/B	C/B
3	Tetapaga Lake (extreme western portion)	C/B		C
4	Tetapaga Lake (in bay leading to Tetapaga River)	C/B		C
5	Tetapaga Lake (off mouth of inflow from Vermilion Lake)	C/B		C
6	Tetapaga Lake (in portion of Lake east of the dam)	C/B		C
7	South Pit			C
8	Outlet of Vermilion Lake Tailings Area (below alum addition)	C	C/B	C/B
9	Iron River (at culvert downstream of outlet from Iron Lake)	C	C	C/B
10	Tetapaga Bay (at mouth of Tetapaga River)	C/B		C
11	Tetapaga Bay (≈100 yards off mouth of Tetapaga River)	C/B		C
12	Tetapaga River (at rapids upstream of mouth)			C/B
13	Reference stream (at crossing of Hwy. 11 just south of Milne-Sherman Road)			C/B
14	Lake Temagami - Northeast Arm station used for Lake Temagami Survey August 11 and 31			C

C = Chemical
B = Biological

FIGURE 1.2.1 SKETCH MAP OF SHERMAN MINE AREA SHOWING SAMPLING STATION LOCATIONS

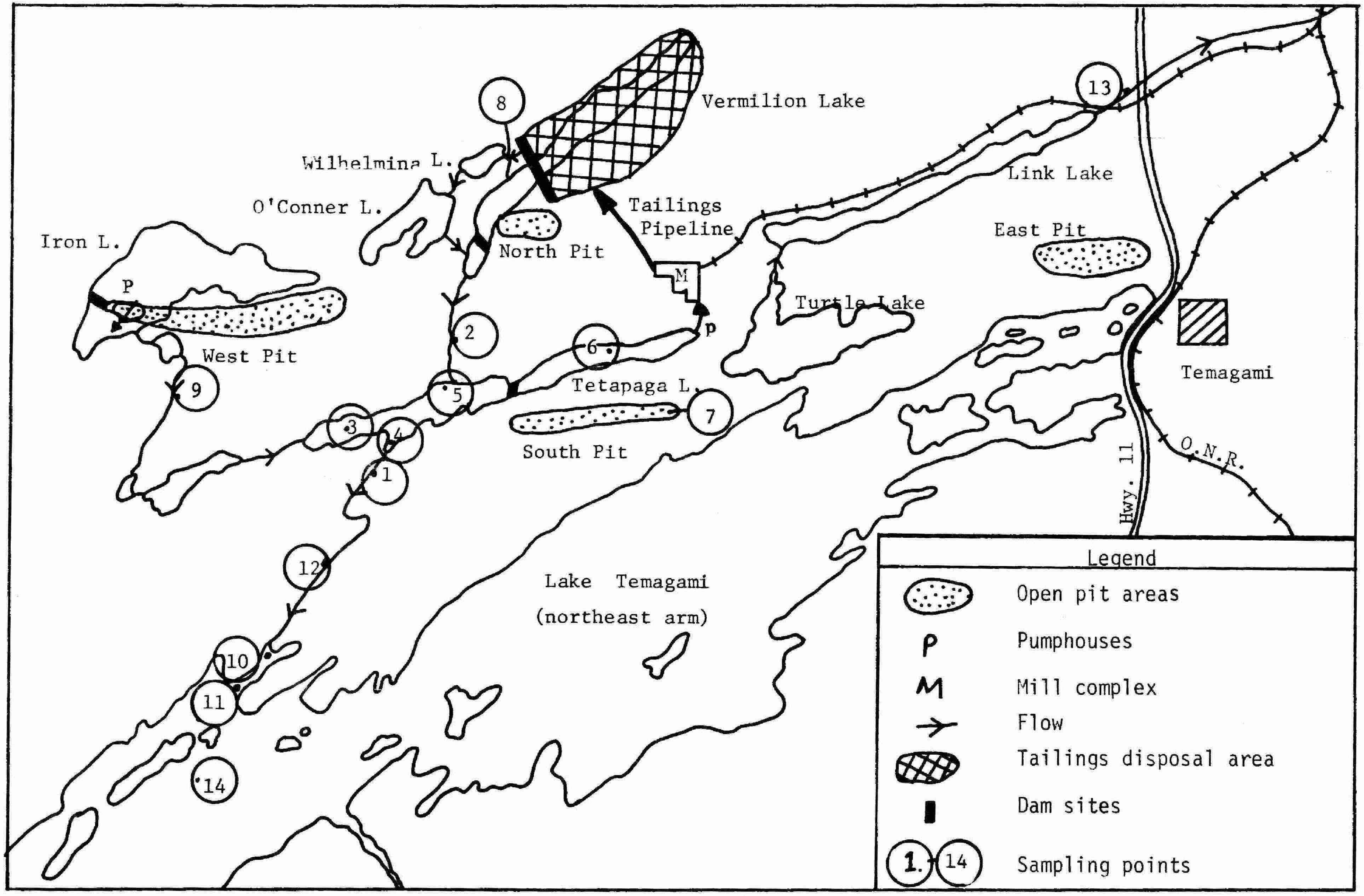


TABLE 1.3.1

MAJOR LIQUID WASTE AREAS AND RECEIVING WATERS FROM THE SHERMAN MINE

SOURCE	TYPE	RECEIVER	COMMENTS
Mill Complex	Tailings	Tetapaga River	Chemically treated with a floculating agent at the decant.
Mill Complex	Spillage from pumping and thickener area	Link Lake	Wastes are collected in a small pond and seep to Link Lake through a sand dam.
Mill Complex	Shop drainage	Tetapaga Lake	Storm sewer conveys wastes to Tetapaga Lake near the pump house - plans call for recycling this waste stream.
South Pit	Surface and ground water	--	The pit is not active and will be allowed to fill.
East Pit	Surface and ground water	--	No de-watering is expected in the near future. No mining activity in this pit to date.
North Pit	Surface and ground water	Vermilion Lake tailings area	Not presently being used. However, plans call for a massive stripping programme. Water to be pumped to the tailings area.
West Pit de-watering	Surface and ground water	Tetapaga River	Kept dry by de-watering Iron Lake. The water is pumped into Tetapaga Lake via Iron Creek.

1.4 Potential Hazards to Water Quality

Base-metal mining typically has serious environmental consequences and has caused large-scale water pollution problems. For example, German, 1972, identified seven serious problems resulting from mining activity in the Manitouwadge area of Ontario, including pH depression, de-oxygenation of bottom waters, toxic concentrations of ammonia, zinc, copper and iron and total elimination of bottom-dwelling macroinvertebrates, an important link in the aquatic food chain.

Experience has demonstrated that the recovery of iron-ore from essentially non-sulphuric ore deposits such as those mined at the Sherman complex poses significantly less hazard to water quality than does metal recovery from sulphuric deposits. However, as indicated by Caplice and Shikaze, 1970, whenever large quantities of finely subdivided mining materials are disposed of on surface (a necessary consequence of all mining and milling operations), problems do occur, including:

"(a) Water Pollution - arising from the leaching of soluble matter from the tailings into a watercourse; erosion occurring on the dam slope as a result of seepage.

(b) Air Pollution - wind blowing of fine dust from abandoned areas; a potential water pollution problem from the windblown dust also exists.

(c) Aesthetic Pollution - the sterile waste piles do nothing to enhance the landscape of the surrounding area."

These three types of problems are present in varying degrees at most mining operations.

Additionally, experience has shown that some mining operations cause an abnormal colouration of waste-receiving waters. A small fraction of the tailings from non-sulphuritic iron-ore is of a very fine particle size (clay) and is resistant to settling in the tailings disposal area. A small concentration of this material being carried over in the decant is sufficient to cause an abnormal colour in the receiving waters. Aerial observation of the Sherman Mine area revealed that an abnormal green colouration existed downstream of the tailings decant.

2. METHODS

2.1 Biology

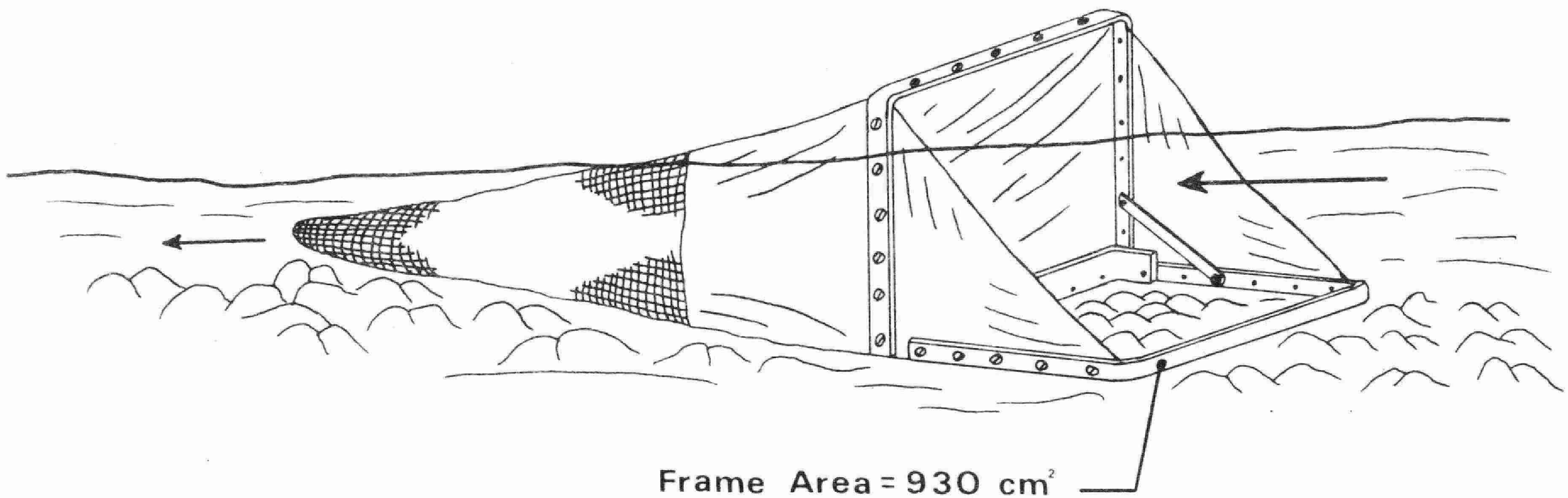
At each of the six stream stations, bottom fauna were sampled by means of a Surber Sampler - an apparatus consisting of two square brass frames hinged at right angles. One frame forms the perimeter of the 930 cm^2 (1 $ft.^2$) area to be sampled and the other supports a fine-mesh collecting net (see figure 2.1.1). The sampler is placed on the stream bottom in a riffle area with the open end facing upstream and the area of the bottom within the frame is disturbed to dislodge bottom-dwelling organisms which are then washed into the retaining net by the force of the stream current. The bottom fauna captured in the net were preserved in 30 ml vials of 70% ethanol for subsequent identification and enumeration.

The surber samples were supplemented by qualitative samples collected by disturbing the bottom immediately upstream of a 15 cm (6 inch) diameter hand seive. The hand seived samples were collected over a timed interval of 15 minutes.

At each station two surber samples and one 15 minute qualitative sample were collected to define the bottom-fauna community.

FIGURE 2.1.1

Surber Stream Bottom Sampler



2.2 Water Chemistry

Water samples for chemical analyses were collected at six stream stations and seven lake stations. At each location duplicate 1-litre samples in glass bottles and single 1-litre samples in polyethylene bottles were collected for analysis at the Ministry of the Environment's Rexdale Laboratory. The samples collected in polyethylene bottles were acidified with sufficient nitric acid to reduce the pH to less than 3.0 in order to prevent metallic ions from precipitating out of solution. Field measurements of pH, conductivity, temperature and dissolved oxygen were taken at selected stations. The stations where samples were obtained for chemical analysis are provided in Table 1.2.1 and Table 2.2.1 indicates the analyses performed.

TABLE 2.2.1

SUMMARY OF CHEMICAL ANALYSIS PERFORMED ON SAMPLES FROM SHERMAN MINE SURVEY, 1972

Copper	Sodium	Silica	Ammonia
Zinc	Potassium	Sulphate	Nitrate
Nickel	Calcium	Chloride	Nitrite
Cadmium	Magnesium	Total Phosphorus	Total Kjedahl
Arsenic	pH (lab.)	Soluble Phosphorus	Total Solids
Iron	Alkalinity		Suspended Solids

2.3 Supplementary Observations

During aerial and ground reconnaisance of the Sherman Mine complex certain observations were made which were relevant to the discussion of the results of this survey. The observations were recorded and are discussed in Section 4.

3. RESULTS

3.1 Biology

The results of the identification and enumeration of stream invertebrates from the various surveys are provided in Tables 1A, 1B, and 1C of the Appendix.

During the pre-operational and the first post-operational surveys (1967-68 and 1969 respectively) considerably more effort per station was devoted to the collection of invertebrates and consequently the numbers of individuals collected are higher than in 1972. Immature mayflies of the families Baetidae and Heptagenidae , and the midge larvae (Tendipedidae) dominated the stream bottom in the areas sampled at that time.

In August, 1972, the sampling effort per station was lower but the number of locations sampled was increased since, as the mining operation progressed, the number of areas that potentially might be affected increased. The results of the biological sampling at that time were very similar to the earlier efforts. At the six stations sampled the maximum number of taxa occurred at stations 1 and 13 where six taxa were represented. Immature mayflies of the families Baetidae and Heptagenidae and immature blackflies (Simuliidae) were common to both stations. Caddisfly larvae, amphipods and the beetle family Dytiscidae were represented at the reference station 13 while dragonflies of the family Coenagrionidae and two families of Diptera (Tendipedidae and Culicidae) were represented at station 1.

The lowest number of taxa was found in samples collected at station 8 at the decant from the Vermilion Lake tailings area where a large number of caddisfly larvae of the family Hydropsychidae were collected as well as a single aquatic spider.

In 1972, blackfly larvae (Simuliidae) were common to all stations except station 8 and caddisfly larvae of the family Hydrosphsychidae were collected at all stations except station 1.

Biological diversity is a measure of the distribution of the community representatives amongst the various taxa and is expressed in this report as Margelef's Index of Diversity. It is calculated as follows:

$$D = \frac{M-1}{\log_e N} \quad \text{where:}$$

D= diversity

M= number of taxa

N= number of individuals.

The measure of species diversity aids in determining the extent of water quality degradation.

In unpolluted water the community is typically composed of a wide variety of organisms with no single form numerically dominating, providing high diversity. Pollution specializes the environment and many of the niches (functional zones) which are available in the natural situation are eliminated. This elimination of niches reduces the number of different types of organisms which are capable of surviving, thus restricting the diversity. In quantitative terms Margelef's Index of Diversity is maximum when all individuals belong to different species and is minimum (0) when all individuals belong to the same species.

The diversity of selected stream stations is provided in Table 3.1.1 below.

TABLE 3.1.1

BIOLOGICAL DIVERSITY OF STREAM INVERTEBRATE COMMUNITIES

VICINITY OF SHERMAN MINE

STATION	DATE	DIVERSITY
1	1967-68	1.8
	1969	1.6
	1972	2.3
2	1967-68	1.6
	1969	2.4
	1972	1.7
8	1972	0.1
9	1972	4.3
12	1972	3.6
13	1972	2.2

The highest diversity occurred at station 9 (Iron River, 1972). This high diversity existed even though the number of taxa represented was less than at other stations because the number of individuals in all taxa was low. The lowest biological diversity occurred at station 8 at the decant from the Vermilion Lake tailings area in 1972. It was not possible to obtain a representative sample from this station in 1967-1969.

At station 1 the diversity ranged from a low of 1.6 in 1969 to a high of 2.3 in 1972. An intermediate value of 1.8 occurred in 1967-68 (mean of 4 samplings). At station 2 the highest diversity occurred in 1969 at 2.4. In 1967-68 and 1972 the diversity was similar

at 1.6 and 1.7 respectively. With the limited amount of sampling, this range (1.6 - 2.4) probably represents the normal variation at a station owing to biological and sampling variability.

3.2 Water Chemistry

The results of the chemical analysis of water for selected stations in the vicinity of the Sherman Mine complex are provided in Tables II, III and IV of the Appendix. Since more intensive water chemistry information was collected in 1972 than during the other investigations the discussion of 1972 data is provided in greater detail. Comparisons with earlier survey results are provided where applicable.

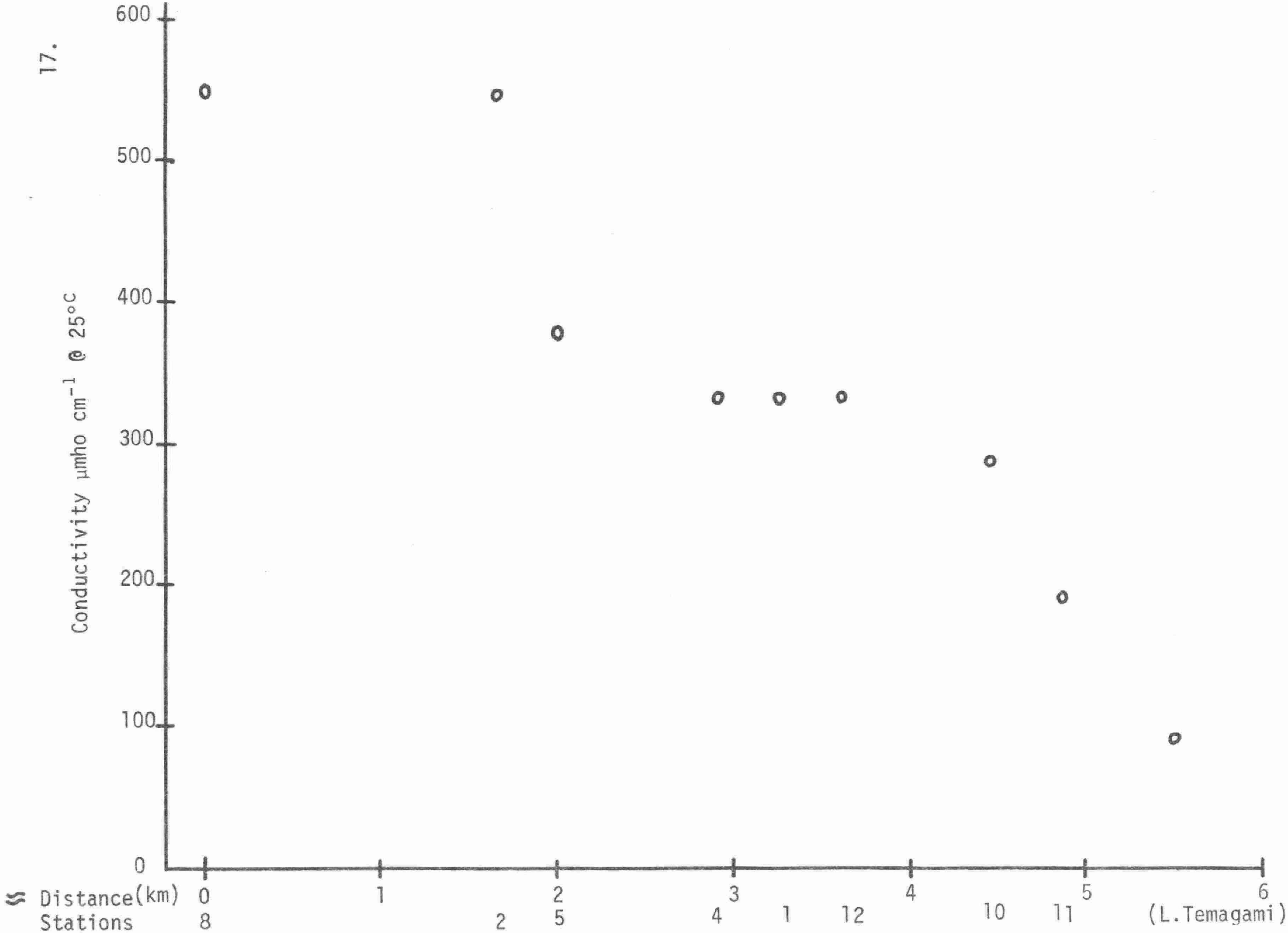
pH, Conductivity and Dissolved Oxygen

The pH of water ranged from slightly acid; pH = 6.34 to slightly alkaline pH = 7.51 except at station 7 (the South Pit) where an extremely acid pH of 2.10 was recorded in this isolated body of water.

Conductivity measurements (only recorded in 1972) varied from 192 to 3000 μmho cm^{-1} at 25°C. The maximum value was recorded at station 7 (the South Pit) and the minimum value at station 11 in Tetapaga Bay of Lake Temagami. Conductivity decreased from the Vermilion Lake tailings area toward the mouth of the Tetapaga River. This information is provided in Figure 3.2.1.

The conductivity of water in Tetapaga Bay (190 μmho cm^{-1} at 25°C) was approximately two times higher than water in the Northeast Arm of Lake Temagami (85 μmho cm^{-1} at 25°C).

FIGURE 3.2.1 GRAPH OF CONDUCTIVITY OF WATER WITH DISTANCE FROM SHERMAN MINE TAILINGS DECANT



The dissolved oxygen concentration remained close to saturation (70 - 96%) throughout the system as measured during the August, 1972 study. Since dissolved oxygen depletion has rarely been found to be a problem downstream of base metal operations only selected stations were sampled during the survey. The dissolved oxygen data are summarized in Table 3.2.2.

TABLE 3.2.2

DISSOLVED OXYGEN CONCENTRATION AT SELECTED STATIONS IN THE VICINITY OF SHERMAN MINE AUGUST 1972

STATION	LOCATION	OXYGEN mg l^{-1}	OXYGEN % SAT.
1	Tetapaga River (at #1 Weir)	7	78
2	Unnamed creek (at #2 Weir)	8	86
3	Tetapaga Lake (extreme western portion)	8	80
8	Outlet of Vermilion Lake Tailings Area (below alum addition)	9	95
9	Iron River (at culvert downstream of outlet from Iron Lake)	8	85
10	Tetapaga Bay (at mouth of Tetapaga River)	9	96
11	Tetapaga Bay (≈100 yards off mouth of Tetapaga River)	8	86
12	Tetapaga River (at rapids upstream of mouth)	7	70
13	Reference stream (at crossing of Hwy. 11 just south of Milne-Sherman Road)	7	76

Heavy Metals

The results of analyses for selected heavy metals are shown in Table III of the Appendix.

Station 7 (the South Pit) showed copper, nickel and zinc concentrations approximately two orders of magnitude higher than other sampling locations, while cadmium and arsenic were not significantly elevated. The bottom water sample from station 6 showed an iron concentration of 12.0 mg l^{-1} and station 7 was 0.92 mg l^{-1}. The range in total iron for the remaining 16 samples was from 0.05 mg l^{-1} to 0.48 mg l^{-1} excepting a single value of 0.97 at station 8 in 1968 prior to overflow from the tailings area.

Table 3.2.3 summarizes the data for selected metal analysis for the August, 1972 sampling, comparing selected stations.

TABLE 3.2.3

CONCENTRATION OF SELECTED HEAVY METALS, VICINITY of SHERMAN MINE

	Range All Stations Excluding #7	Station#7	Tetapaga Bay Station#11	Reference Station #13
Cu	0.00 -<0.03	0.36	0.003	0.005
Ni	<0.004 -<0.04	0.70	0.007	<0.004
Zn	0.003 - 0.05	0.81	0.017	0.004
Cd	N/D -<0.01	<0.01	0.001	0.001
As	<0.01	<0.01	<0.01	<0.01

NOTE: The same lower detection limit was not utilized in all analyses (see Appendix table III)

N/D = Not detectable

Major Cations

The results of the analyses for major cations in 1972 are provided in Table IV of the Appendix. The mean and the range for this data is provided in Table 3.2.4.

TABLE 3.2.4

MEAN AND RANGE OF MAJOR CATIONS

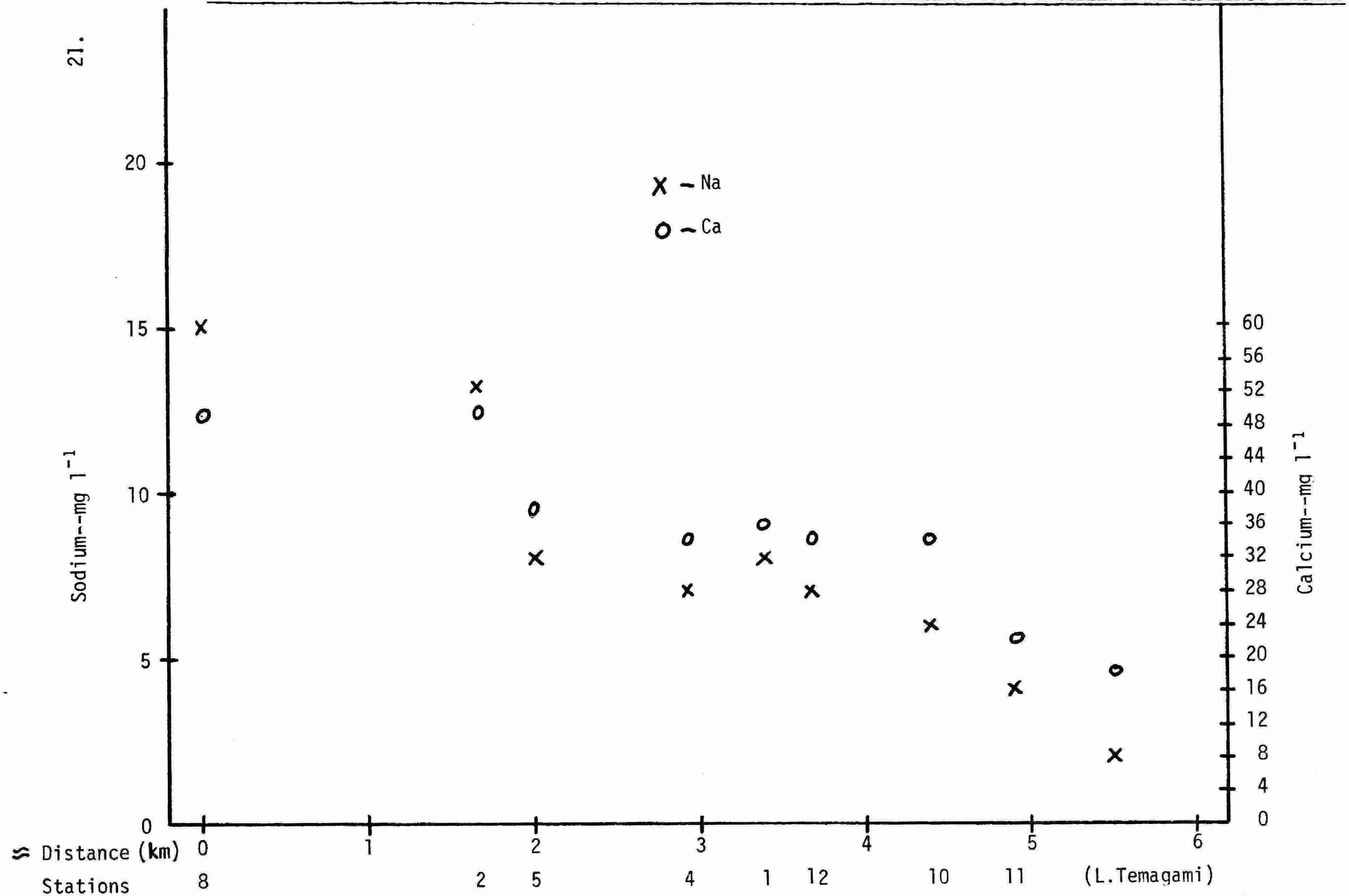
VICINITY OF SHERMAN MINE, 1972

	Mean	Range	Station 7
Sodium	8	4 - 15	
Potassium	6	2.6 - 20	
Calcium	38 *	22 - 51	254
Magnesium	14 *	8 - 26	125

* Excluding the South Pit station 7

The concentration of major cations diminished with distance from the Vermilion Lake Tailings decant as demonstrated in Figure 3.2.2 for sodium and calcium.

FIGURE 3.2.2 GRAPH OF SODIUM AND CALCIUM CONCENTRATION WITH DISTANCE FROM SHERMAN MINE TAILINGS DECANT



Major Anions

The concentrations of sulphate, chloride and bicarbonate (alkalinity) are provided in Table IV of the Appendix and the mean and range values are summarized in Table 3.2.5. In Table 3.2.6 the concentration of major ions is converted to milliequivalents per litre.

TABLE 3.2.5

MEAN AND RANGE OF MAJOR ANIONS

VICINITY OF SHERMAN MINE LIMITED, 1972

	Mean	Range	Station 7	Station 8	Lake Temagami
Sulphate	107	59-204	1180	184	14-23
Bicarbonate	65	37-103	79	103	16-18
Chloride	10.0	5-20	13	20	-

All values in mg l^{-1}

Bicarbonate expressed as alkalinity as $CaCo_3$.

TABLE 3.2.6

MEAN CONCENTRATION OF MAJOR ANIONS

VICINITY OF SHERMAN MINE, 1972

EXPRESSED AS MILLIEQUIVALENTS PER LITRE

	Mean	Station 7	Station 8	Lake Temagami
Sulphate	2.22	24.5	3.83	0.350
Bicarbonate	1.34	1.58	2.06	0.334
Chloride	0.299	0.37	0.56	0.085

NOTE: 1. SO_4^{-2} mg l^{-1} x 0.02082 = SO_4^{-2}meq l^{-1}

2. Alk as $CaCO_3$ x 1/.8202 = HCO_3^-mg l^{-1}

HCO_3^- mg l^{-1} x .01639 = HCO_3^- meq l^{-1}

3. Cl mg l^{-1} x 0.02821 = Cl^- meq l^{-1}

At the discharge point, station 8, the anions were in the following order of predominance (meq l^{-1});

$SO_4 > HCO_3 > Cl$ while in Lake Temagami $SO_4 = HCO_3 > Cl$.

Sulphate decreased by ten fold from the discharge point at station 8 to Lake Temagami at station 14 while bicarbonate and chloride decreased by approximately six fold in the same distance.

3.3 Supplementary Observations

On the basis of aerial and ground reconnaissance in the vicinity of Sherman Mine the following pertinent observations were recorded.

1. Water in the Vermilion Lake tailings area was an intense aqua colour and this colouration was observed to extend into Wilhelmina Lake. At the outlet of O'Connor Lake little of this unnatural colouration remained.
2. During the initial reconnaissance of the mine area (August 16) the water in the south pit was observed to be distinctly red-brown in colour. On revisiting the south pit during the survey (August 29) the water colour had changed to pea green.

3. At station #9 on the Iron River, the water was observed to be brownish and a coating of hydrated iron oxide covered the stream bottom.
4. The small pond receiving spillage from the tailings pumping station and thickener area was observed to be a rusty brown colour. Also, this colour extended along the shore of adjacent Link Lake near the periphery of the retaining pond.
5. A rusty brown colour was observed in the shallows along the road embankment at the eastern end of Tetapaga Lake.
6. A rusty brown colour was evident along the intermittent stream covering portions of the road to weir #1.

4. DISCUSSION

4.1 General Water Quality

The water quality variables capable of exerting a direct lethal effect on aquatic biological communities such as pH, heavy metals and dissolved oxygen were within the limits considered normal for watercourses in the Precambrian Shield with the exception of localized high concentrations of iron. Table 4.1.1 provides the range in concentration of selected metallic ions considered to be toxic to fish and other aquatic life, and the maximum value achieved in the receiving waters in the vicinity of the Sherman Mines complex.

TABLE 4.1.1

COMPARISON OF TOXIC CONCENTRATIONS OF SELECTED METAL IONS AND CONCENTRATIONS PRESENT IN RECEIVING WATERS VICINITY OF SHERMAN MINE, 1972

	Arsenic	Cadmium	Copper	Iron	Nickel	Zinc
Range in Toxic Concentration	1.1-234	0.01-1.05	0.01-0.048	0.56-100	0.7-6.0	0.56-1.35
Maximum value in receiving water, vicinity of Sherman Mine	< 0.01	< 0.01	< 0.03	12	< 0.04	0.05
Source	3	1	1 & 2	1	1	1 & 2

1 = Ministry of the Environment, 1972

2 = O.W.R.C., 1970

3 = McKee & Wolf, 1963

All values in mg l^{-1} (total metallic ion)

As mentioned, the only metal which exceeded the minimum toxic concentration quoted above was iron (12.0 ppm). This value was recorded for a sample collected in the bottom waters of Tetapaga Lake. It is likely that this high iron value is related to inputs from surface runoff streams in the east end of Tetapaga Lake (as noted in supplemental observations) and/or as a result of the earlier practice of pumping south pit mine water directly into the lake. Iron concentrations in the surface waters of Tetapaga Lake ranged from 0.08 to 0.30 mg l^{-1} while bottom waters ranged from 0.15 to 12.0 mg l^{-1}.

The iron concentration at the outlet of Tetapaga Lake (station 1) was higher than at the outflow to the Vermilion Lake tailings area, - station 8 (0.48 and 0.27 mg l^{-1} respectively) a reflection perhaps of the past accumulation of iron in Tetapaga Lake. At Lake Temagami (stations 10 and 11) the values were 0.21 and 0.17 mg l^{-1} respectively.

The aquatic biological community in the vicinity of the Sherman Mine complex was depressed even though no single chemical variable was exerting a direct influence on it at the time of sampling. This is often the case in drainages from mining operations and can be attributed to either the presence of toxic conditions at an earlier time or the reaction of the biota to the general change in water chemistry even though no single variable exerted a direct lethal effect. At station 8, immediately downstream of the tailings decant, the community was represented by large numbers of a single taxa-Hydropsychidae (caddisfly larvae) considered to be tolerant to pollution from mining activity. Their relatively high numbers indicate an extensive community

imbalance. Taxa that would normally have competed with the caddisflies have been eliminated and this form has entirely dominated the community. The water chemistry at this station showed relatively high concentrations of most of the major ions including sodium, potassium, magnesium, sulphate, chloride and bicarbonate. The elevation in these chemical parameters is, no doubt, due to the influence of the water chemistry of the tailings area as well as the polyelectrolyte additions at the discharge point. The low biological diversity at station 8 is a response to the altered water chemistry.

Conditions had not changed significantly at the next downstream station (station 2) as evidenced by a depressed bottom fauna community and continued elevation in the major ion composition of the water.

The first area of notable improvement occurred at station 1 at the outlet of Tetapaga Lake where the community included representatives of the pollution sensitive group of immature mayflies and dragonflies as well as the three taxa of dipterans found during the study. The waterborne concentrations of chemical variables were lower than at upstream stations and higher than at Lake Temagami stations. This information is provided in Figures 3.2.1 for conductivity and 3.2.2 for sodium and calcium. The water quality at this station was not exerting a measurable effect on the bottom fauna community and thus the effluent quality is considered acceptable at this station at the present time.

The findings of the 1969 survey viewed in context of the 1967-68 pre-operational surveys revealed that the bottom fauna community at station 8 had been altered by the waste discharge from the Sherman Mine complex since the only forms present were those which are considered to be tolerant to pollution, and as in the present investigation the community was dominated by immature caddis-fly larvae. However, at that time no impairment of the aquatic ecosystem could be detected downstream of this point. The data presented for the 1972 survey show that impairment extended to station 2, indicating a downstream migration of pollutants from the Sherman Mine complex. This result is not unexpected since the flow at station 2 would be essentially undiluted tailings decant water after an initial flushing of water from Wilhelmina and O'Connor Lakes.

The water quality measured during the 1969 survey was essentially similar to that of the present investigation, although the results in 1969 were narrower in their coverage. Table 4.1.2 compares the results of water chemistry analyses from the 1967-68 pre-operational survey with the results of the 1969 and 1972 post-operational investigations.

TABLE 4.1.2

COMPARATIVE SUMMARY OF CHEMICAL ANALYSES

FROM THE VICINITY OF SHERMAN MINE, 1967-68, 1969 and 1972

	LOCATION #8			LOCATION #2			LOCATION #1		
	1967-68	1969	1972	1967-68	1969	1972	1967-68	1969	1972
Total Solids ppm	239	286	440	182	289	360	110	163	230
Dissolved Solids ppm	213	274	420	179	271	355	77	143	180
pH	7.8	7.4	7.5	7.7	7.2	6.3	7.7	7.2	7.4
Total Iron ppm	0.97	0.5	6.27	0.25	0.6	0.10	0.25	0.5	0.48

An elevation in the dissolved solids concentration at stations 1, 2 and 8 was the only significant change in the receiving waters. This change is probably related to the gradual replacement of water from Wilhelmina, O'Connor and Tetapaga Lakes originating from the pre-operational period by overflow water from the tailings area. The liquid accompanying the raw tailings to the impoundment contains approximately 600 mg l^{-1} dissolved solids which would remain essentially unchanged during retention in the tailings area. The mill water is recycled from water overflowing the tailings area therefore only a small quantity of the overflow water reaches the Tetapaga River. However, since a constant quantity of chemical is added during each mill circuit the base load of that water is continuously increasing.

The suspended solids concentration was not significantly different from year to year indicating that the polyelectrolytic facility provided in 1971 at the decant in an effort to reduce the colour in the effluent is not causing an increase in the suspended load downstream of the decant.

4.2 Evidence of an Acid Mine Drainage Problem

The low pH of water in the South Pit (hydrogen ion concentration one hundred thousand (10^5) times greated than at station 8) and the highly elevated sulphate concentration provide evidence of an acid condition resulting from contact with sulphuritic minerals as described at length by Hawley, 1972.

Although not part of the direct drainage system of the Sherman Mine complex, the South Pit provides evidence of the potential for acid production and hence an acid-mine drainage problem. The condition existing in the South Pit could occur in the other pits in the future if similar circumstances are encountered. As well as increasing the hydrogen ion concentration to levels incompatible with the aquatic ecosystem the typical acid mine drainage contains toxic concentrations of heavy metals. As provided in Table III of the Appendix and Table 3.2.3 the concentrations of copper, nickel and zinc were at least ten times higher at station 7 than at other stations. In addition to the South Pit, as indicated in Section 3.3, several areas in the vicinity of Sherman Mine showed evidence of intermittent drainage carrying high concentrations of hydrated iron oxides. These observations are of little consequence if the source of the iron 'staining' is not from an intermittent acid-leaching problem, however, at least some of these drainages appeared to intersect outcroppings of rock containing significant concentrations of sulphide minerals and would suggest that perhaps an acid leaching problem does exist in these areas.

As an aside it is interesting to consider the observations made on water colour in the South Pit which changed from an apparent reddish-brown to a pea green colour during the period August 16 to August 29 (See Section 3.3). The reddish-brown colour was undoubtedly due to the presence of collodial iron hydroxide particles, an end product of the oxidation of iron sulphides in the presence of water (see Hawley, 1972). The apparent pea green colouration noted on August 29 is probably due to the presence of ferrous sulphate in solution and represented a change in the oxidation state of the iron from Fe^{+3} to Fe^{+2} in that interval of time.

The explanation provided by Stumm and Morgan (1970) for this reaction is the reduction of ferric iron by pyrite leading to a subsequent increase in acidity. i.e. $FeS_2 + 14\ Fe^{3+}$ (in solution from acid-mine situation) $+8H_2O = 15\ Fe^{2+} + 2SO_4^{2-} + 16\ H^+$

4.3 Colouration of Downstream Waters

A further concern related to the milling operation at Sherman Mine is the production of lateritic clay that is discharged to the tailings area. This lateritic material resists settling and is carried over in the tailings decant. Low concentrations of this material are sufficient to cause an apparent colouration of water (by light reflection from the minute particles) and as provided in Section 3.3 there was sufficient concentration in the Sherman Mine effluent to cause a colour change in Wilhelmina and O'Conner Lakes.

Although the particular colouration noted in Wilhelmina and O'Conner Lakes is not considered to be extremely harmful to the aquatic ecosystem it does elicit concern that water quality changes are taking place.

There is some evidence to suggest that this colouration is migrating downstream with continued mining activity. If the coloured discharge reaches Lake Temagami or indeed the Tetapaga River upstream of Lake Temagami it would probably create adverse public reaction to the mining operation. Since there is no proven test to quantify the amount of colloidal material in suspension it is difficult to ascertain if the polyelectrolyte addition is effective in reducing the concentration of laterite to a level which provides for adequate protection of downstream waters from visual impairment. The company is attempting to monitor the condition through an aerial surveillance programme including photographic records.

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Mr. R. C. Hartviksen, Chief Engineer - Geology and Mr.R. G. Garrett, Mining Engineer, Sherman Mine were most helpful in guiding us through the mine property and discussing recent changes in the effluent system. The engineering department is keeping an excellent photographic record of the effluent system which assisted in bringing us up to date on the present status of the mining operation.

The Ministry of Natural Resources provided an aircraft for aerial observation of the mine operation.

Mr. L. W. Fitz, Regional Engineer, Industrial Wastes Branch of this Ministry provided information describing the effluent system and receiving waters for the Sherman Mine complex.

Messrs. W. Bradley and C. Lafrance, student assistants with the Biology Section, assisted in the collection of data for this survey.

APPENDIX

TABLE 1A

RESULTS OF BOTTOM FAUNA SAMPLING FROM SHERMAN MINE SURVEY , 1972

STATION TAXA	1 (Weir #1)	2 (Weir #2)	12 (Tetapaga R.)	9 (Iron R.)	8 (Decant)	13 (Reference)
Mayfly						
Baetidae	2	2	X			X
Heptageniidae	3	4	1			X
Caddisfly						
Hydropsychidae		1	1	X	33	2
Hydroptilidae				X		
Dragonfly						
Coenagrionidae	X					
Diptera						
Simuliidae	2	1	X	1		7
Tendipediae	1					
Culicidae	1					
Stonefly						
Perlidae			1			
Worms						
Tubificidae		2				
Amphipod						
Talitridae						1
Leech						
Hirundinea				1		
Spider						
Araeae					1	
Beetle						
Dytiscidae						X
Number of Taxa	6	5	5	4	2	6
Number of Individuals	9	10	3	2	34	10
Index of Diversity	2.3	1.7	3.6	4.3	.12	2.2

X - Taxa found in qualitative sample

TABLE IB

STREAM INVERTEBRATES FROM TWO STATIONS NEAR SHERMAN MINE DEVELOPMENT

PRE DISCHARGE PERIOD

	Station #1				Station #2			
AUGUST	1967	1968	1967	1968	1967	1968	1967	1968
Nematode	1			2				
Planaria	24		5					
LEECH								
Erpobdellidae					x	1		1
SNAIL								
Valvata					8			
CLAM								
Sphaerium					1	1		
AMPHIPOD								
Hyallela azteca	2		3					1
CLADOCERA								
Daphnia			1					
CRAYFISH								
Orconectes propinquois							x	
MAYFLY								
Heptagenia	11		2					
Baetis		21	7		2	4	1	
Paraleptophlebia						2		
DRAGONFLY								
Coenagrion	1							
Ophiogomphus								
Progomphus					1			
STONEFLY								
Neoperla			x					
BEETLE (adult)			x					
CADDISFLY								
Hydropsyche	37	37	18	4	87	128	121	25
Hydropsyche pupa		3				1		
Polycentropus			3		2			
Chimarra	2		x			6	1	
DIPTERA								
Phalacrocera		3						
Athrix		2			3	4	2	1
Cnephia	14	47	10	197	17	1		3
Prosimulium							7	
Culicoides		1						
Chaoborus								1
MIDGE (Larvae)	6	42	29	4	8	9	2	8
(Pupa)	1		3		2			
MITE	1						1	

TABLE IB - Continued

AUGUST	Station #1				Station #2			
	1967	1968	1967	1968	1967	1968	1967	1968
FISH								
Cottus cognatus				1				
Number of Taxa	11	8	9	5	8	10	8	7
Number of Individuals	101	156	83	208	130	153	136	40

Collected with Surber Sampler
X = Additional taxa collected with hand sieve, 1967.

TABLE IC

STREAM INVERTEBRATES FROM STATIONS NEAR SHERMAN MINE DEVELOPMENT

POST DISCHARGE PERIOD

AUGUST	STATION #1 1969	STATION #2 1969	1969	VERMILION LAKE OUTLET 1969
NEMATODE				
WORM				1
Eclipidrilus		1		
LEECH				
Erpobdellidae	1			
CLAM				
Sphaerium		x	x	
SNAIL				
Physa gyrina	x			
AMPHIPOD				
Hyalella azteca	2			
MAYFLY				
Baetis	3	9	14	
Heptagenia		1	x	
BEETLE				
Larva	1	x	x	
Ochthebius (adult)	1			
MESIPTERA				
Hesperocorixa (adult)	x			
CADDISFLY				
Chimarra		1	2	
Halesus	x			
Hydropsyche	935	43	19	7
Pupa	18	6		x
DIPTERAN				
Atherix		x	x	
Rhaphidolabis			3	
Simulium	3	4	2	78
MIDGE (Larvae)	47	7	5	12
(Pupa)	1			
ACARI (mites)		1		

TABLE IC - Continued

AUGUST	STATION #1 1969	STATION #2 1969	1969	VERMILION LAKE OUTLET 1969
FISH				
Hadropterus maculatus				x
No. of Taxa	11	11	10	5
No. of Individuals	1012	72	45	98

Collected with Surber sampler - x = additional taxa collected with hand sieve.

TABLE II

IN SITU CHEMICAL ANALYSES - VICINITY OF SHERMAN MINE, 1972

STATION	DATE	DEPTH	pH	CONDUCTIVITY µmho/cm^{-1} @ 25°C	D.O. mg l^{-1}	TEMP.
1	29/8/72	n/a	7.27	340	7	19.0
2	"	n/a	6.34	5.45	8	17.5
3	"	surface)		319		20.0
	"	bottom)		685	8	
4	"	surface)	7.1	339		
	"	bottom)		315		
5	"	surface)		378		
	"	bottom)		419		
6	"	surface)		500		
	"	bottom)		469		
7	"	surface	2.10	3000		
8	30/8/72	n/a	7.51	550	9	16.6
9	"	n/a	7.40	290	8	17.0
10	"	surface	7.09	290	9	17.0
11	"	surface	7.22	192	8	17.5
12	31/8/72	n/a		340	7	14.0
13	"	n/a		320	7	18.0

n/a = not applicable - stream station.

TABLE III

CONCENTRATIONS OF HEAVY METALS FROM SHERMAN MINE SURVEY, 1972

STATION	DATE	DEPTH	Cu	Ni	Zn	Cd	As	Fe
1	29/8/72	n/a	0.00	.004	.003	< .001	<.01	.48
2	"	n/a	0.00	.006	.006	.002	<.01	.10
3	"	bottom	<0.03	<0.04	0.03	<0.01	<.01	.11
4	"	surface	<0.03	<0.04	0.01	<0.01	<.01	.11
	"	bottom	<0.03	<0.04	0.04	<0.01	<.01	.15
5	"	surface	<0.03	<0.04	0.01	<0.01	<.01	.08
	"	bottom	<0.03	<0.04	0.05	<0.01	<.01	.32
6	"	surface	<0.03	<0.04	0.03	<0.01	<.01	.30
	"	bottom	<0.03	<0.04	0.04	<0.01	<.01	12.0
7	"	surface	.36	.70	.81	<0.01	<.01	.92
8	30/8/72	n/a	.004	.004	.006	.002	<.01	.27
9	"	n/a	.002	.005	.006	.001	<.01	.38
10	"	surface	.008	.008	.011	.002	<.01	.21
11	"	surface	.003	.007	.017	.001	<.01	.17
12	31/8/72	n/a	.006	< .004	.009	n/d	<.01	.15
13	"	n/a	.005	< .004	.004	.001	<.01	.05

All values expressed in mg l^{-1}

n/a - not applicable - stream station

n/d - not detectable.

TABLE IV CHEMICAL ANALYSES OF WATER SAMPLES FROM SHERMAN MINE SURVEY, 1972

									Nitrogen as N				Phosphorus as P				pH	Solids	
Stn.#	Date	Depth	Na	K	Ca	Mg	SiO_2	SO_4	NH_3	Kjel	NO_2	NO_3	Tot.	Sol.	Alk.	Cl	at lab.	Tot.	Susp
1	29/8/72	N/A	8	8.1	36	14	3.6	92	.08	.51	.011	.23	.013	.002	67	9	7.4	230	50
2	29/8/72	N/A	13	16.0	50	22	2.7	128	.11	.56	.008	.55	.011	.002	96	18	7.7	360	5
3	29/8/72	S	6	6.5	34	10	1.4	78	.06	.52	.009	.19	.008	.003	64	8	7.5	180	5
		B	6	5.6	31	8	2.0	73	.07	.59	.008	.15	.006	.001	59	7	7.4	140	0
4	29/8/72	S	7	7.1	34	12	2.0	81	.06	.47	.009	.20	.011	.002	66	9	7.6	200	0
		B	7	6.3	34	11	2.0	77	.14	.66	.009	.16	.011	.002	68	8	7.4	200	0
5	29/8/72	S	8	8.6	38	15	2.0	108	.26	.52	.010	.27	.018	.004	72	10	7.8	240	5
		B	8	7.8	42	16	2.0	120	.16	.53	.011	.30	.014	.002	83	12	7.5	240	10
6	29/8/72	S	9	10.0	49	17	1.1	162	.06	.35	.006	.31	.006	.002	52	13	7.4	350	10
		B	4	3.3	50	21	1.6	204	.09	.34	.007	.37	.006	.022	42	13	6.9	380	0
7	29/8/72	S	13	12	254	125	4.1	1180	.90	1.39	.016	1.30	.36	.004	79	6	3.3	270	15
8	30/8/72	N/A	15	20	51	26	6.6	184	.04	.29	.043	1.00	.019	.002	103	20	7.8	440	20
9	30/8/72	N/A	7	2.7	44	10	3.8	79	.06	.64	.034	.85	.033	.015	79	6	7.6	270	15
10	30/8/72	S	6	6.2	34	12	2.2	92	.05	.50	.008	.18	.008	.002	60	8	7.4	220	5
11	30/8/72	S	4	3.4	22	8	0.2	59	.04	.35	.006	.05	.006	.002	37	5	7.4	150	2
12	31/8/72	N/A	7	6.8	34	11	2.4	82	.05	.52	.008	.19	.009	.002	64	10	7.4	--	--
13	31/8/72	N/A	5	2.6	38	9	2.5	86	.05	.39	.006	<.01	.011	.002	44	10	7.1	--	--

All results in mg l^{-1}
N/A = not applicable - stream stations
B = bottom
S= surface NOTE: station # 6B total and soluble phosphorus values appear to be reversed

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